Managing Climate Risks

Roger M. Cooke[1,2], Carolyn Kousky[1]
[1]Resources for the Future
[2]Dept Math. TU Delft
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Key Points

- Why Risk Management?
- Total Uncertainty = Model + Parameter
- Climate Damage: Inner and Outer Measure

Rational Decision Theory

- A rational agent maximizes expected utility
- (subjective) probability and utility unique *to individual*
- Climate change is a group decision problem
- Professional risk takers don’t manage risk by bending the utility function of a ‘representative consumer’
- Probabilistic Design: optimize performance under risk constraint

Risk Management Approach

- Risk-averse representative consumer

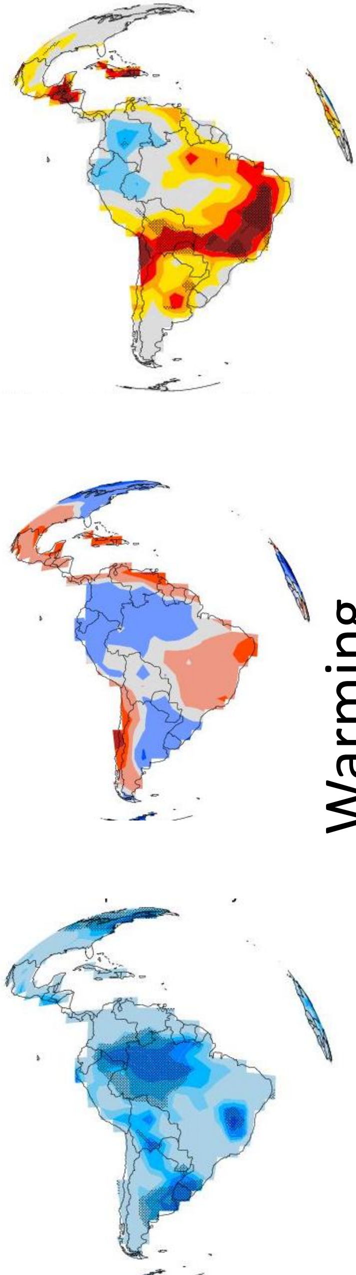
  - Discounting
  - Utility function
  - Utility of civilization

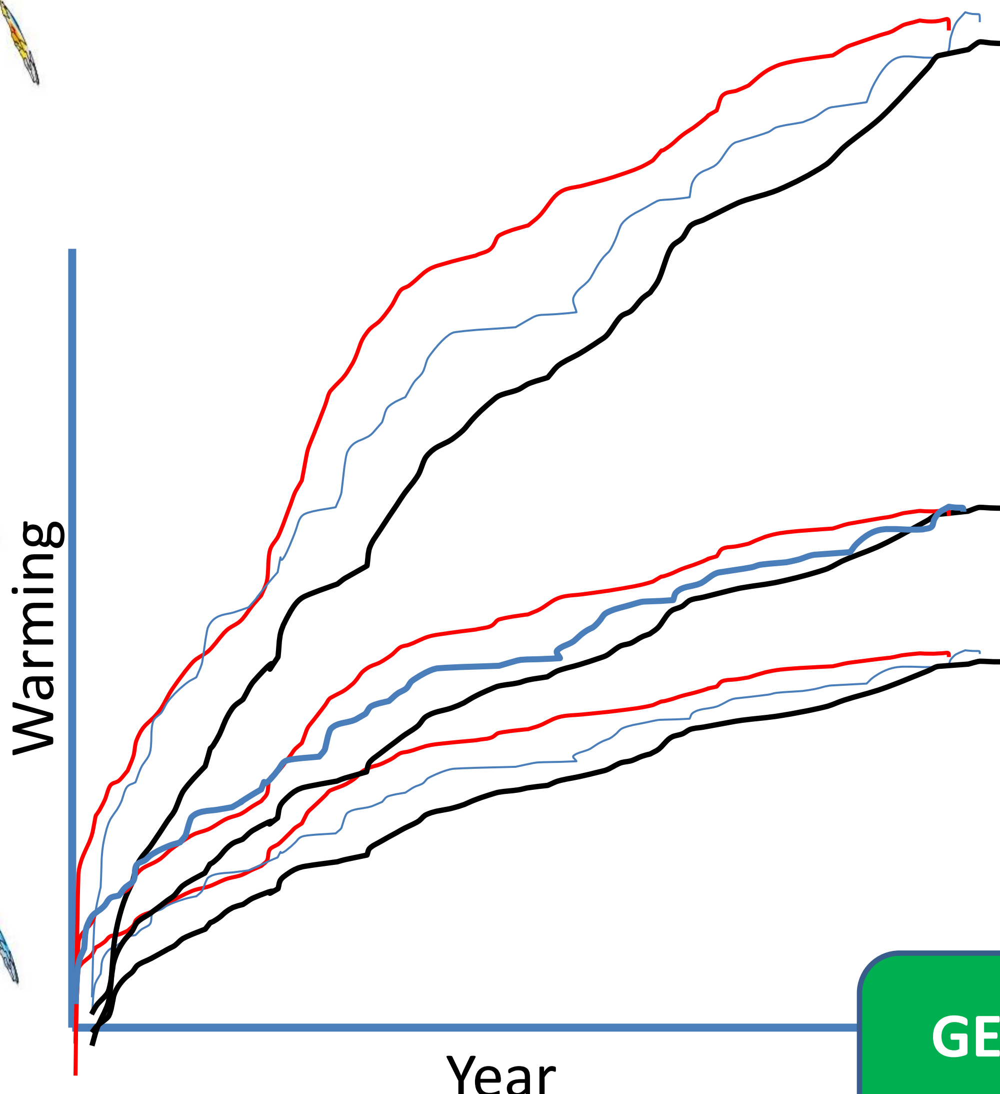
And / Or

- Risk-constrained optimization

  - Capture total uncertainty
  - Choose probability constraints for set of DAI’s
  - Find efficient ways to satisfy constraints

Pricing Carbon at the Margin





Assume values of climate variables

Compute path

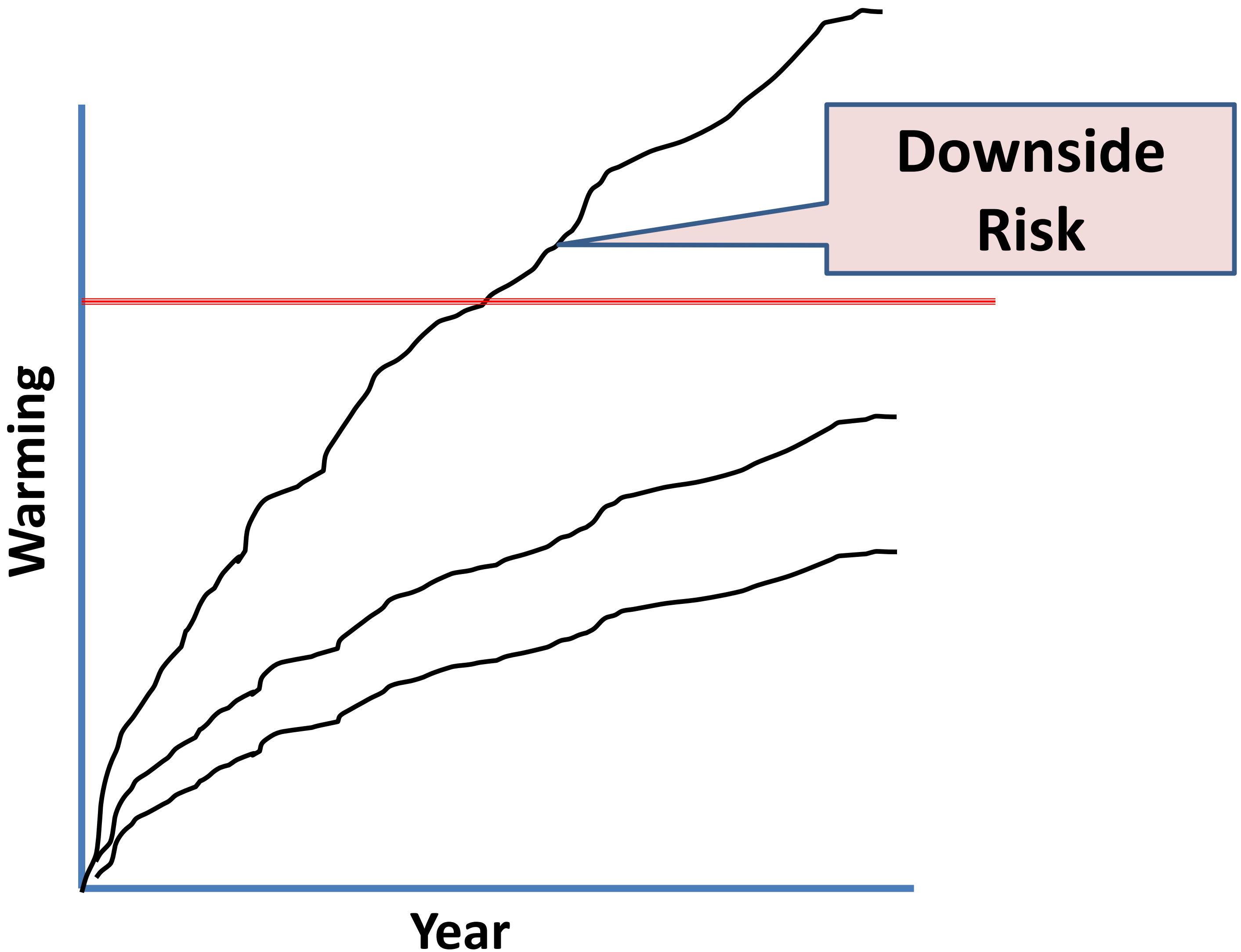
Compute NPV of damages from Δ1 t C

Different damage model

Different SOW

GET distribution over marginal cost of carbon

Buying Down Risk



Model Uncertainty

- Stress test
- Canonical variations

Stress Test DICE Growth Model

Λ = abatement, A = total factor productivity, K = capital stock, N = labor, δ = depreciation

$$\textbf{Output(t)} = \frac{[1-\Lambda(t)]\, A(t)\, K(t)^{\gamma}\, N(t)^{1-\gamma}}{(1 + .0028\,\mathrm{Temp}(t)^2)}$$

$$K(t+1) = (1-\delta)\, K(t) + \mathrm{Output}(t) - \mathrm{Consump}(t)$$

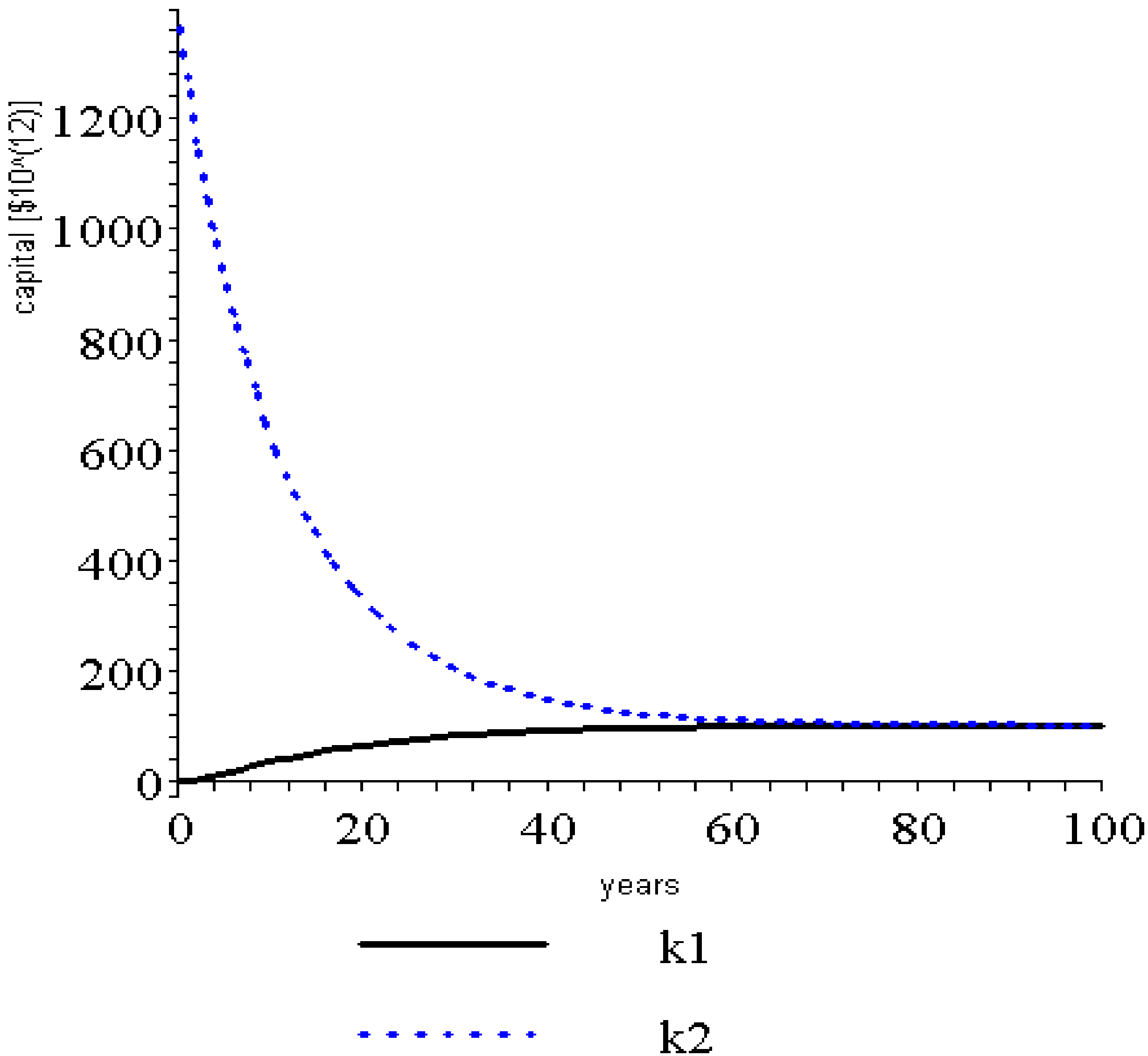
Bernoulli Equation Consump(t)=η(t)Output(t) :

$$dK/dt = -\delta K(t) + B(t)K(t)^{\gamma};$$

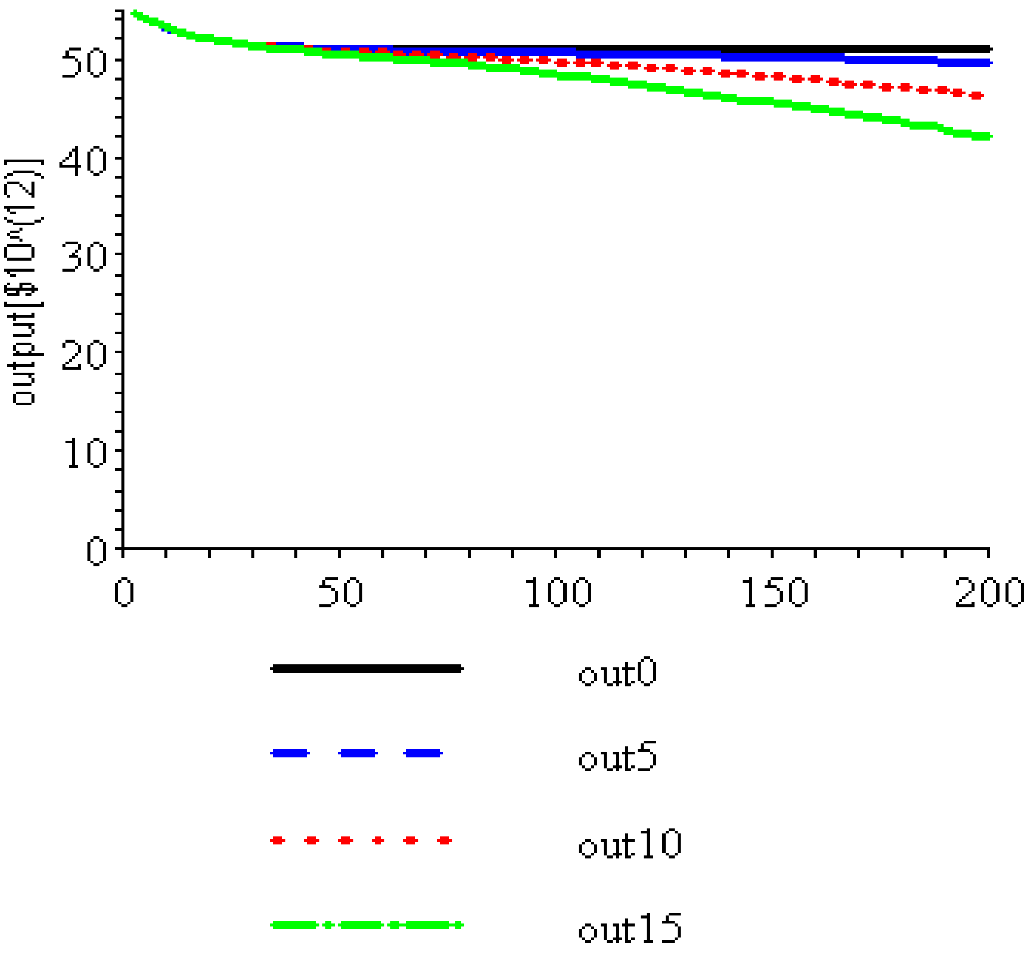
Put Temp(t) $\equiv$ 0; A(t) $\equiv$ A; N(t) $\equiv$ N; Λ(t) $\equiv$ 0; η(t) $\equiv$ η

$$K(t) = [(1-\gamma)\, B\int_{x=o..t} e^{-(1-\gamma)\delta x}\, dx \quad + e^{-(1-\gamma)\delta t}\, K(0)^{(1-\gamma)}]^{1/(1-\gamma)}$$

Two capital trajectories with DICE values, no temperature rise, no abatement K1(0) = 1$ and K2(0) = 1370 trillion $



Output[Trill $], outx(t) is output at time t with linear temperature increase of x [C] in 200 years with starting capital C = 137 [Trill $]



Canonical Variations

- Do other simple model forms

  have structurally different behavior?

Lotka Volterra instead of Bernoulli Model

$$GHG(t+1) = (1-0.0083)GHG(t) + 0.024 \times GWP(t)$$

Emissions proportional to Gross World Output
(Kelly & Kohlstadt 2001)

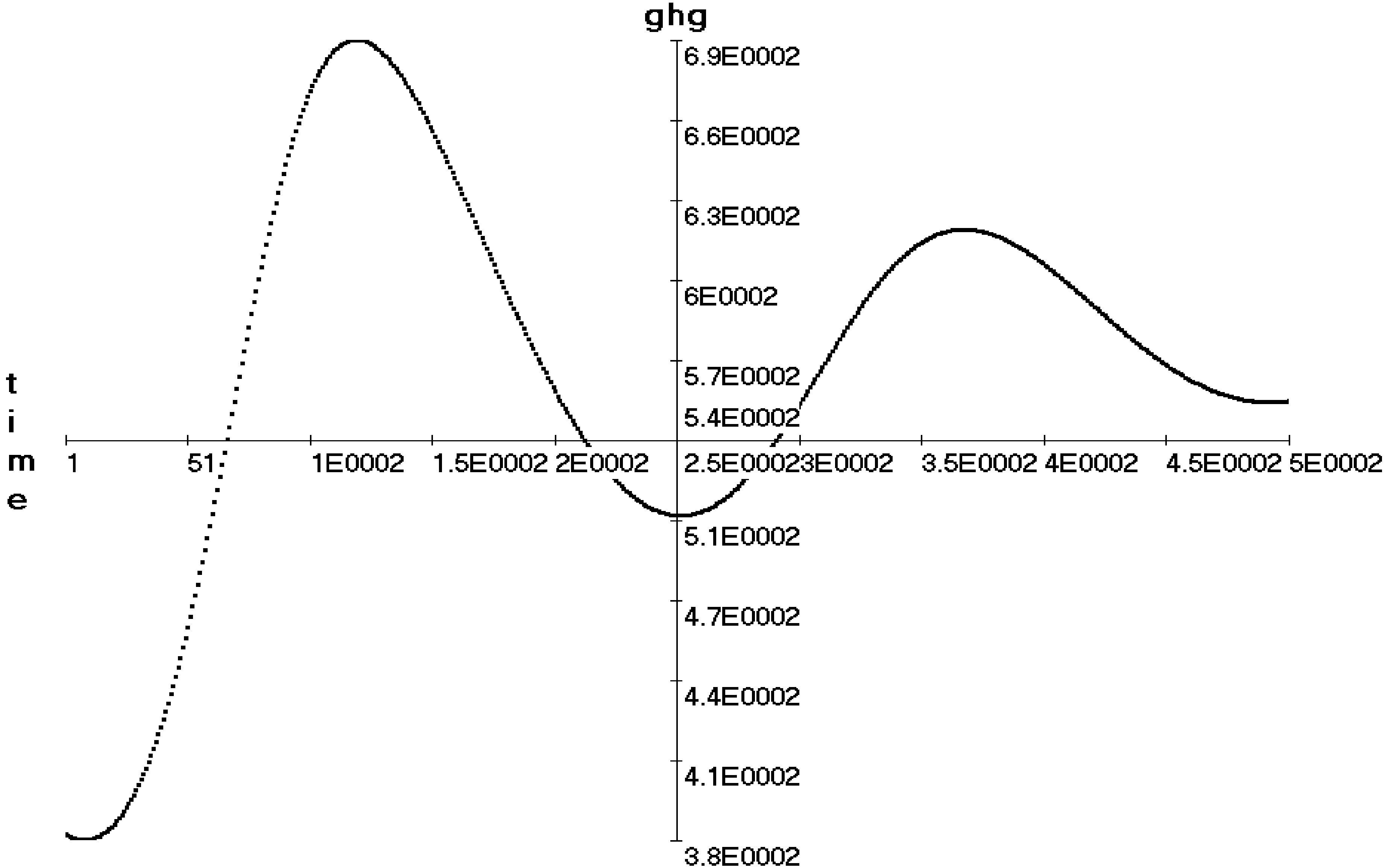
$$GWP(t+1) = [1+0.03 - D(T(GHG(t)))] \times GWP(t)$$

Gross World Output Growth Rate
(World Bank, last 48 yrs)

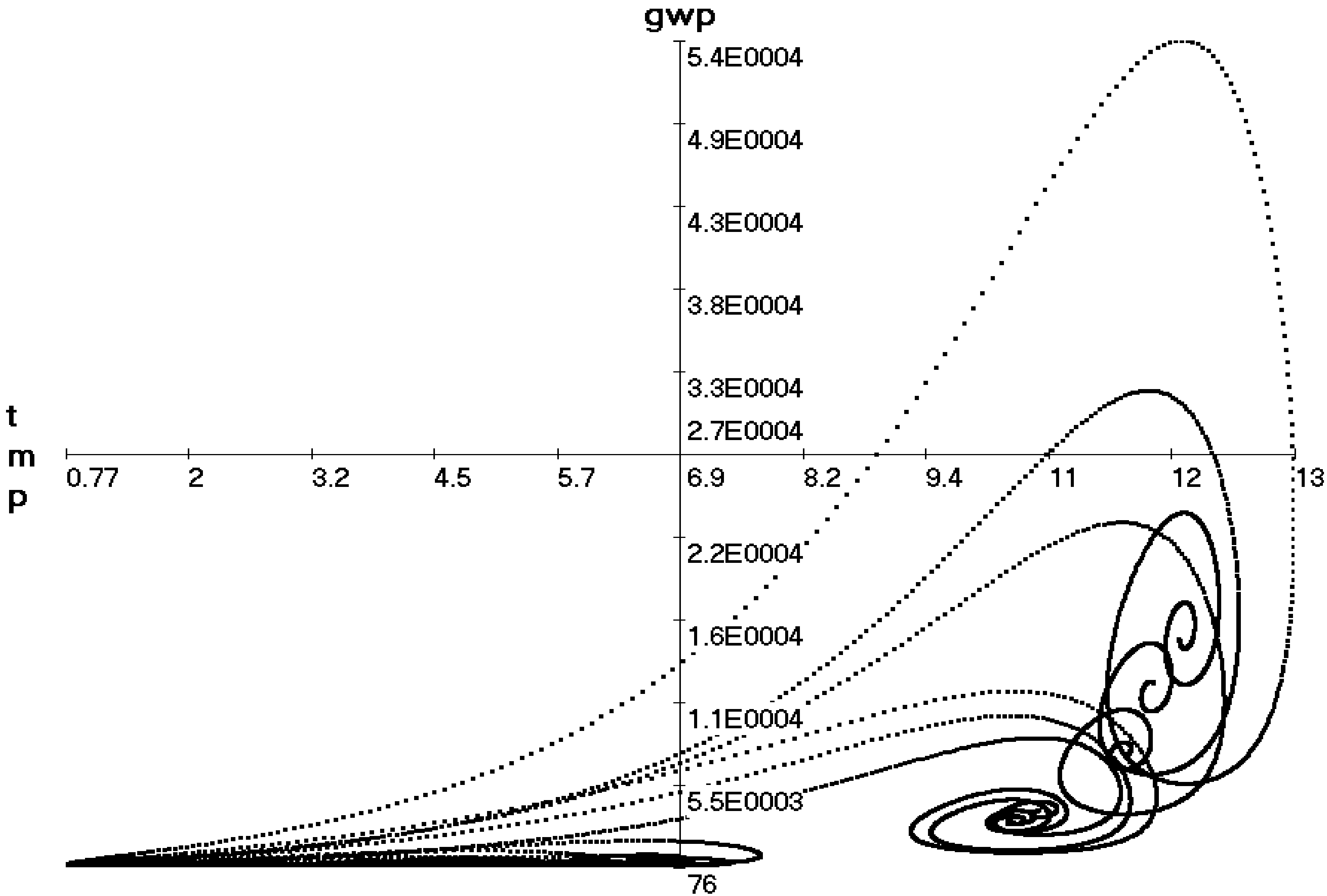
$$D(GHG)(t) = (T/18)^2$$

Weitzman's Death Temperature

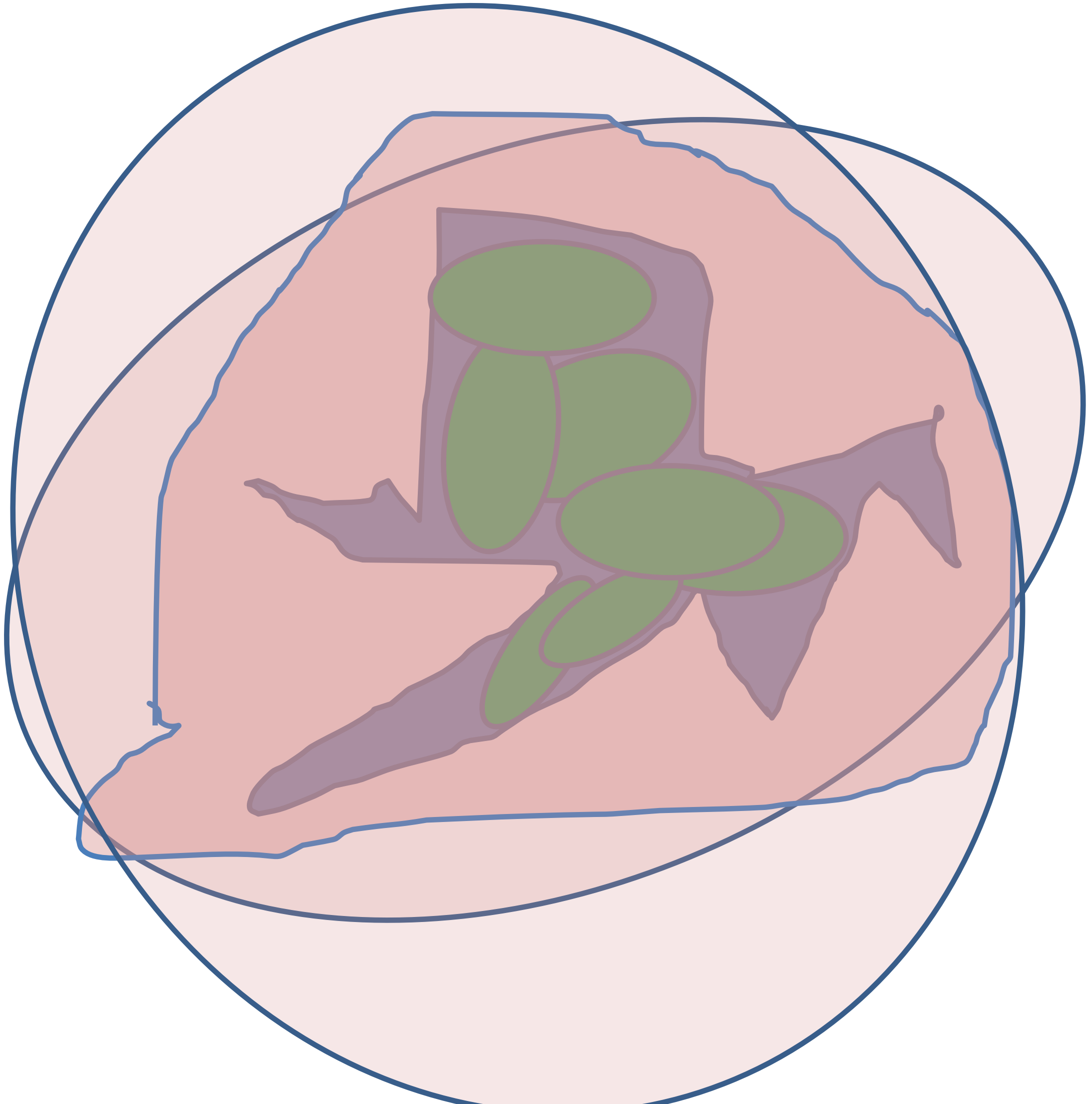
Different Behavior



Phase Portraits, w / wo Dependence



Damage: Inner & Outer Measure



Deal with Model Uncertainty?

- Fit your models to data?
- Fit your models to probabilistic data from Structured Expert Judgment
- Bayes Model Averaging
- ….

Yale G-Econ Database: Gross Cell Product

GCPpp Time average growth rate:

[Ln(GCPpp) – min[lnGCPpp)] / 400

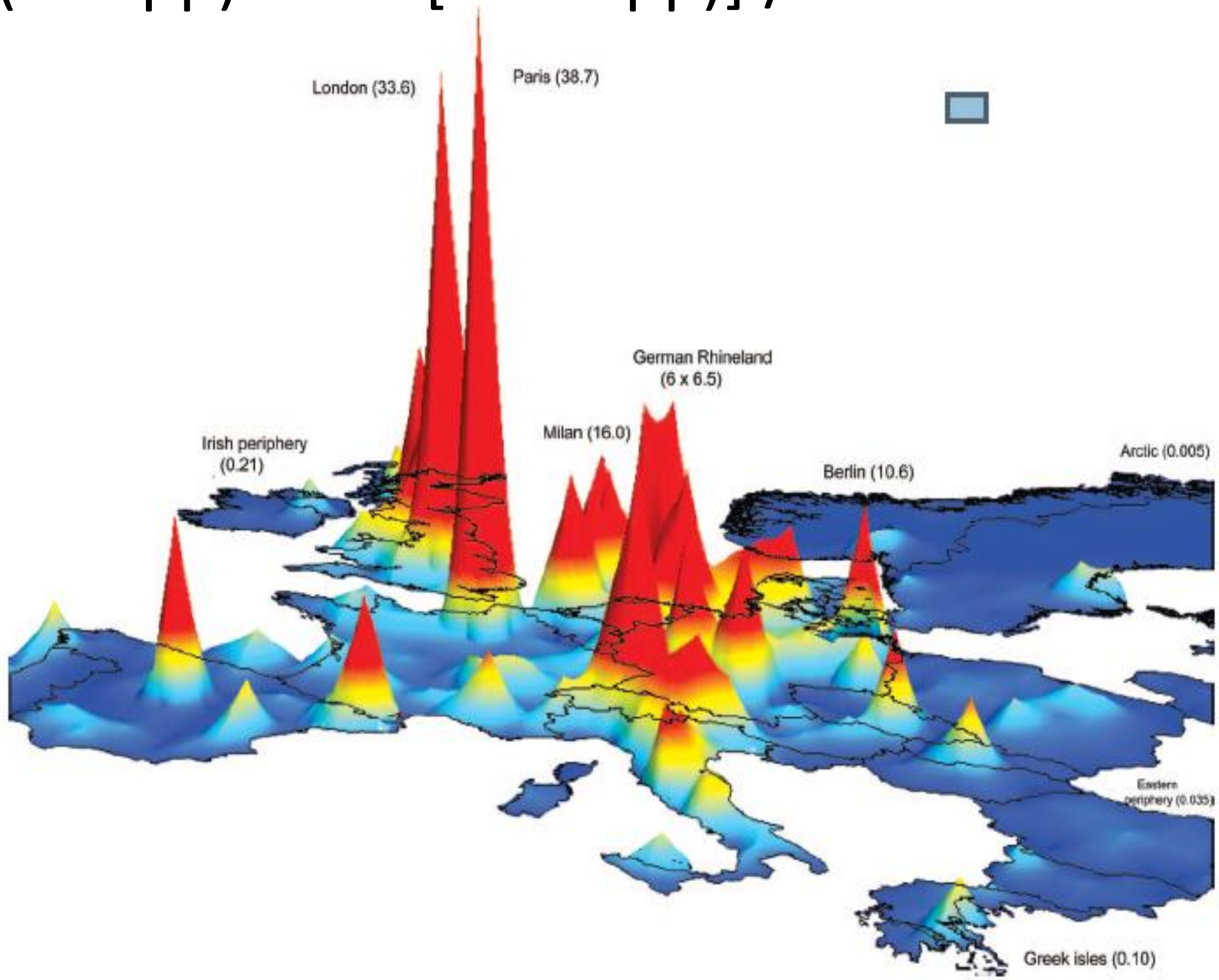
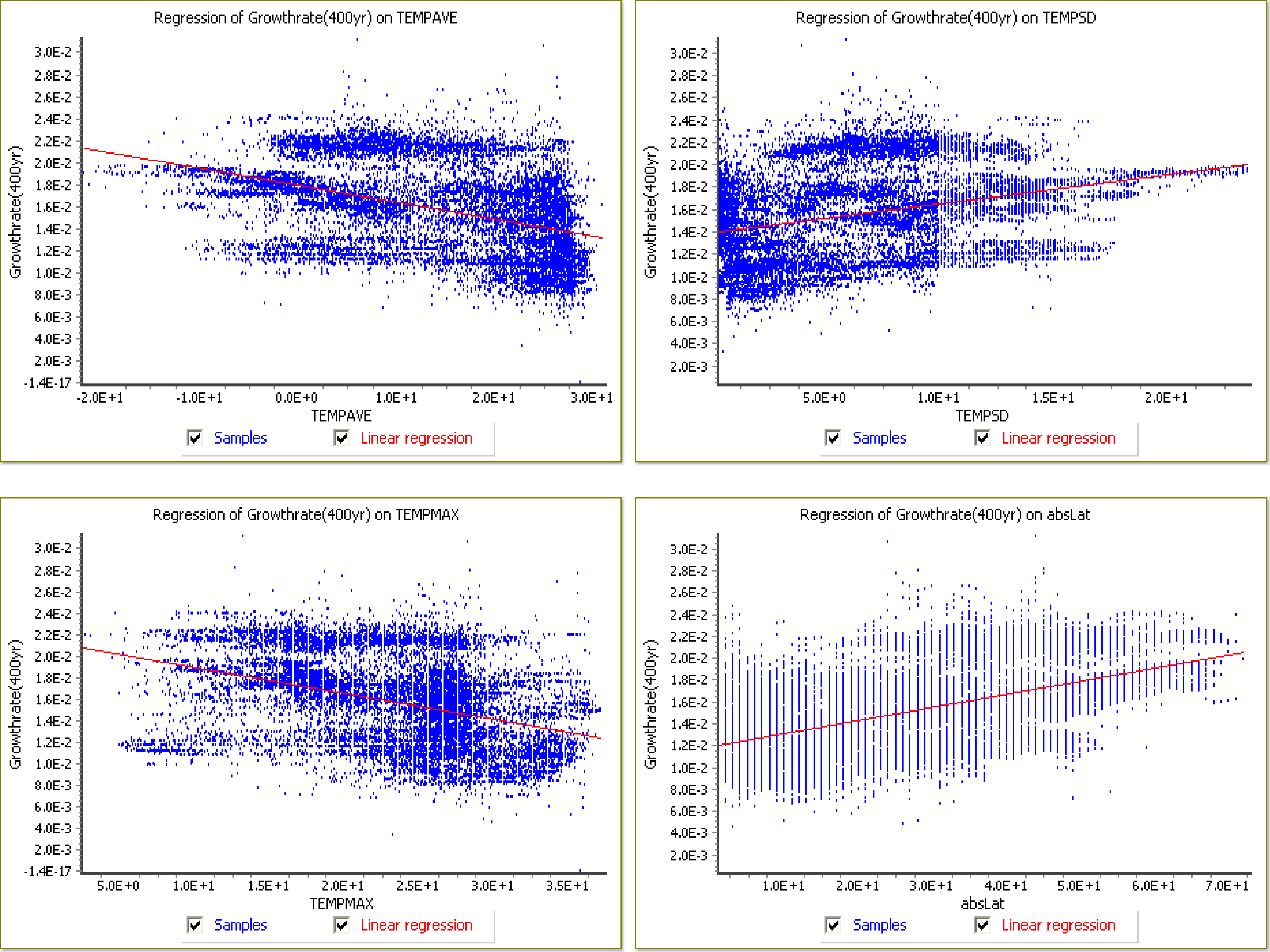
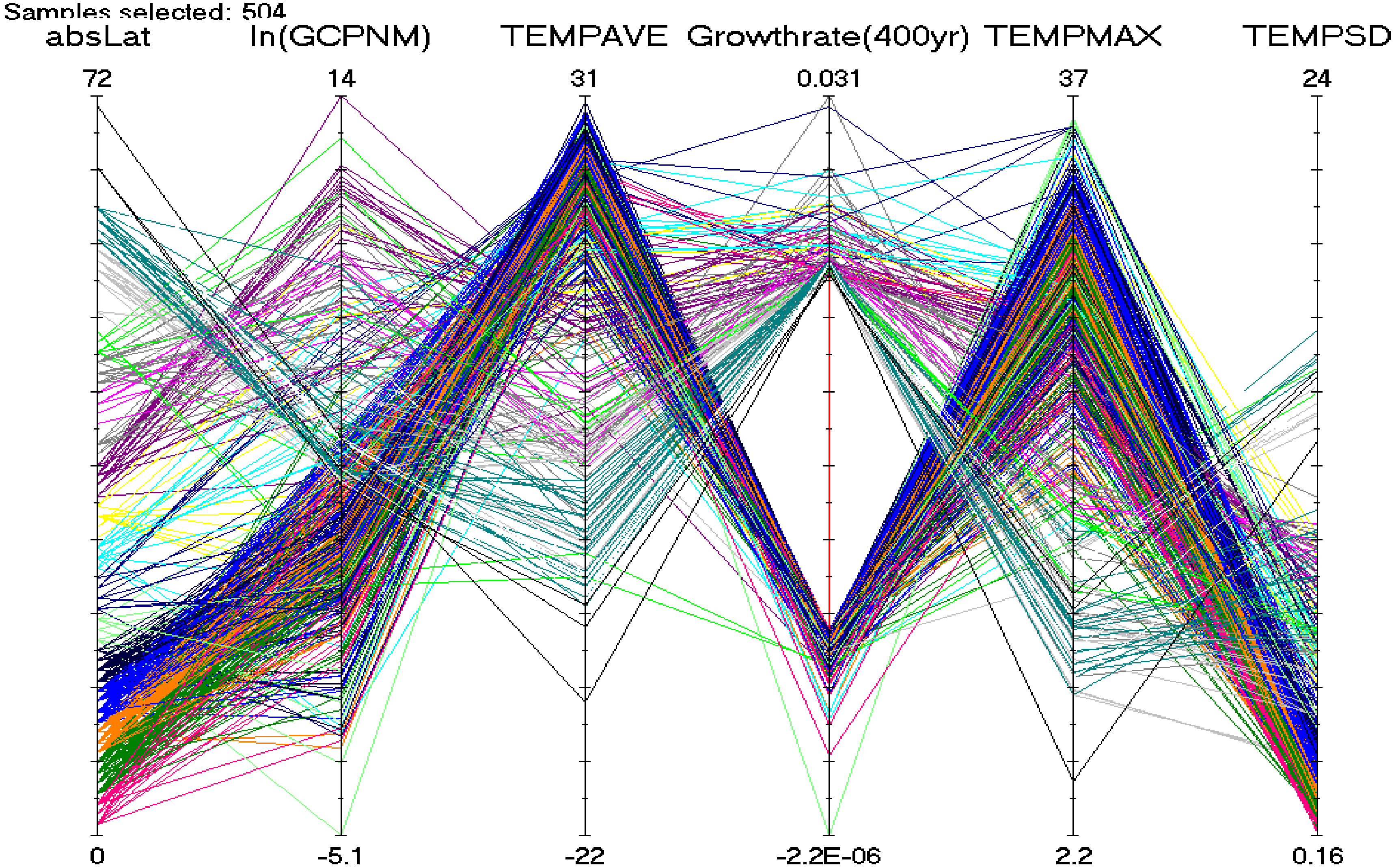


Fig. 1. Economic map of Europe. This figure shows an economic topographical map of Europe with heights proportional to gross domestic product per area Note how economic activity clusters in the core, whereas the periphery has much lower economic elevations. The observations measure economic activity i millions of 1995 U.S. dollars per km² at a 1° latitude by 1° longitude scale.


Regression of Growthrate(400yr) on TEMPAVE
Growthrate(400yr)
TEMPAVE
Samples
Linear regression
Regression of Growthrate(400yr) on TEMPSD
Growthrate(400yr)
TEMPSD
Samples
Linear regression
Regression of Growthrate(400yr) on TEMPMAX
Growthrate(400yr)
TEMPMAX
Samples
Linear regression
Regression of Growthrate(400yr) on absLat
Growthrate(400yr)
absLat
Samples
Linear regression

Joint Distribution as Cobweb Plot

Conditional on top and bottom 1% growth rates



Factor multiplying GCPpp when changing only TEMPAVE +3C

	Indep Vbl	Covariate	Partial reg coeff	Factor
Model 1	ln(GCPpp)	TEMPAVE	-0.06167	0.831095973
Model 2	ln(GCPpp)	absLat	0.083428	1.388541617
		TEMPAVE	0.109418	
		TEMPMAX	-0.09706	
Model 3	ln(GCPpp)	absLat	0.088856	0.892180333
		TEMPAVE	-0.038029	
		TEMPMAX	0.047788	
		TEMPSD	-0.222984	
Model 4	ln(GCPpp)	TEMPAVE	-0.121162	0.695248461
		TEMPMAX	0.041572	
		TEMPSD	-0.103743	

Conclusions

- Need to tackle model uncertainty
- Need to converge ‘inner’ and ‘outer’ damage models

What Are Predicted Impacts of Warming?

- 5^{o}C
  - collapse of Greenland ice sheet
  - large-scale eradication of coral reefs
  - disintegration of West Antarctic ice sheet
  - shut-down of thermohaline circulation
  - millions of additional people at risk of hunger, water shortage, disease, or flooding

    (Parry, Arnell, McMichael et al. 2001; O'Neill and Oppenheimer 2002; Hansen 2005)

- 11-12°C
  - regions inducing hyperthermia in humans and other mammals "would spread to encompass the majority of the human population as currently distributed"

    (Sherwood and Huber 2010)

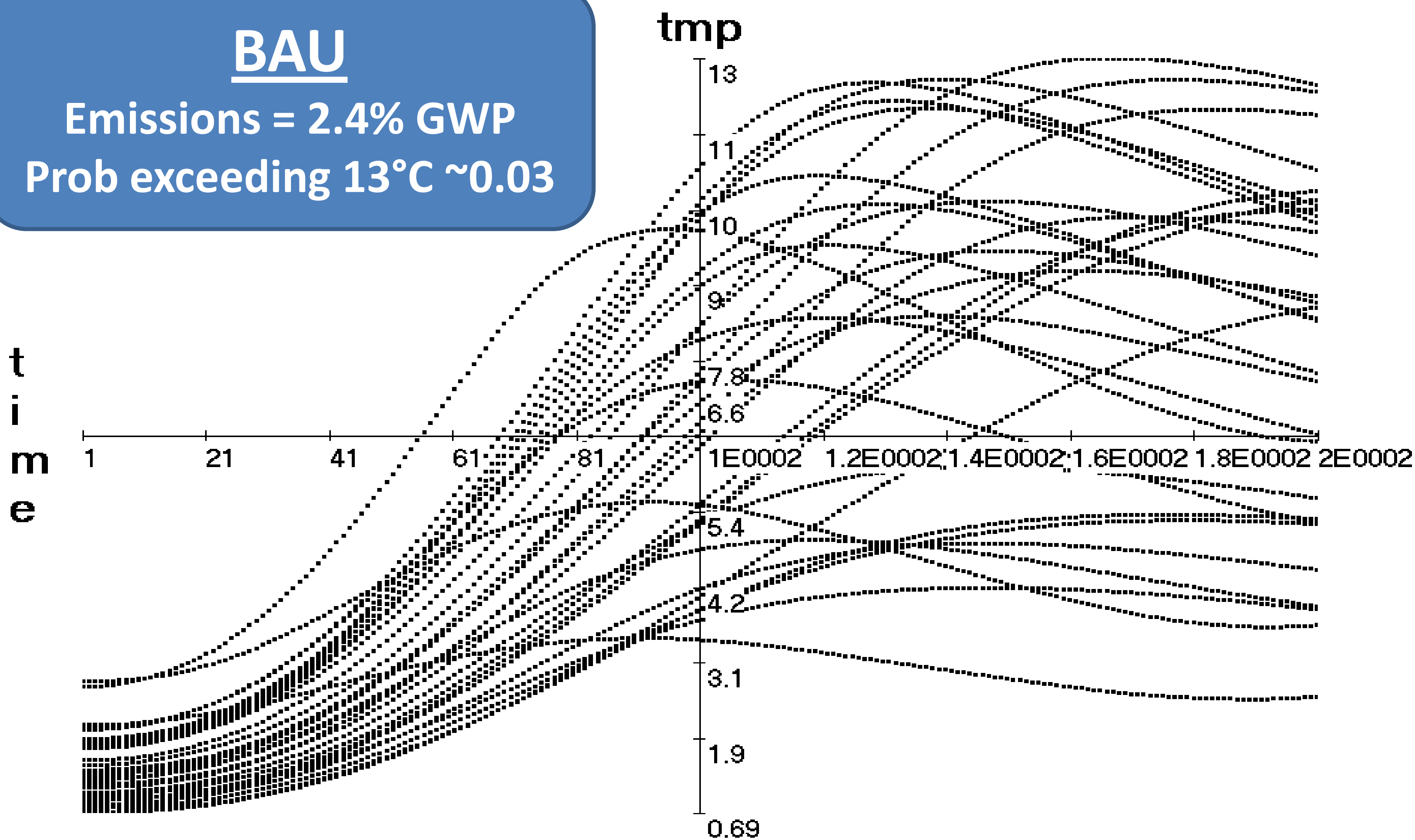
Value@Risk *(Basel II Protocol)*

Banks reserve capital to cover "1-in-200 yr" loss event

BAU

Emissions = 2.4% GWP

Prob exceeding 13°C ~0.03



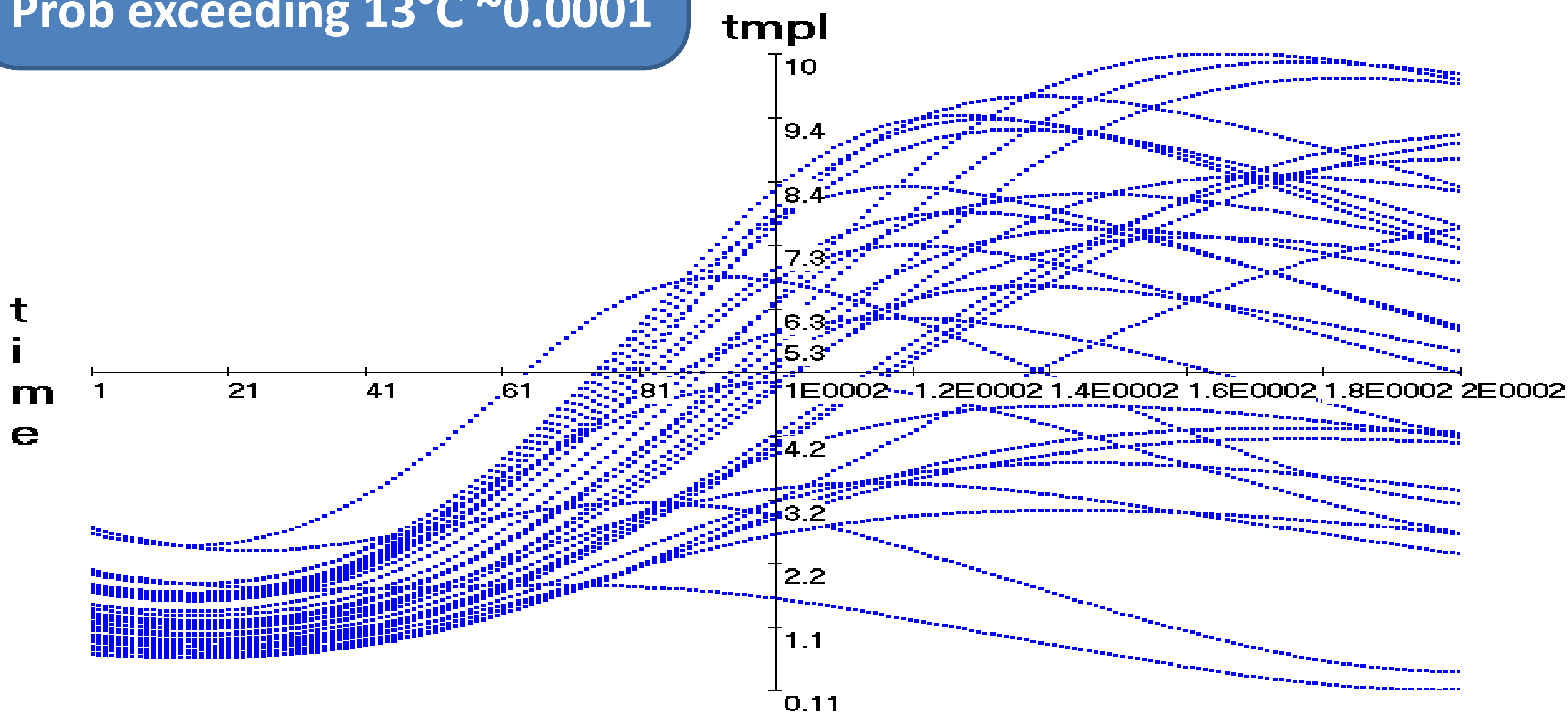
Value@Risk *(Basel II Protocol)*

Banks reserve capital to cover “1-in-200 yr” loss event

Stringent

Emissions = 1.5% GWP

Prob exceeding 13°C ~0.0001



Risk Constraints

- PROB{ $\Delta T > 13°C$ for 500 yr} < 0.0001
- PROB{Greenland ice sheet melts in 300 yr} < 0.001
- PROB{Oceans become net C emitter in 100 yr} < 0.01
- ***What is the price?***